Journal of Coastal Research	SI 64	1425 - 1429	ICS2011 (Proceedings)	Poland	ISSN 0749-0208

The effects of sewage discharge on the water quality of the beaches of São Luís (Maranhão, Brazil)

W. N. Trindade†, L. C. C. Pereira†*, D. de O. Guimarães†, I. R. da Silva†, R. M. da Costa†
† Instituto de Estudos Costeiros,
Universidade Federal do Pará,
Bragança, 68600-000, Brazil
*E-mail: cajueiro@ufpa.br

ABSTRACT

Trindade, W.N., Pereira, L.C.C., Guimarães, D. de O., Silva I.R. da and Costa, R.M. da, 2011. The effects of sewage discharge on the water quality of the beaches of São Luis (Maranhão, Brazil). Journal of Coastal Research, SI 64 (Proceedings of the 11th International Coastal Symposium), 1425 – 1429. Szczecin, Poland, ISSN 0749-0208

The population of São Luís Island has grown considerably in recent years, resulting in serious environmental problems, such as the discharge of sewage directly onto local beaches. In the present study, the effects of this discharge on the quality of the water were evaluated at four local beaches. Meteorological and oceanographic data were obtained for different seasonal conditions: December (dry season, minimum river discharge); March (rainy season, increasing discharge); June (rainy season, maximum discharge); and September (dry season, declining discharge). In March, the tides and wave significant heights were highest, and the tidal currents the fastest. The highest concentrations of nitrates and phosphates were recorded in June, mainly in Ponta de Areia and São Marcos, which is influenced by the discharge of the São Marcos estuary. In December, the highest concentrations of nitrite and relatively high levels of phosphate were recorded, as were the highest concentrations of thermotolerant coliforms, at two of the beaches (Ponta de Areia and São Marcos). At Calhau and Olho d'Água, the highest concentrations of thermotolerant coliforms were recorded in March. The data suggest that the high concentrations of dissolved nutrients recorded in June were related to the high fluvial discharge during this month, while those recorded in December (together with high coliform levels) appeared to be related to the increased numbers of beachgoers visiting the area during this period, together with the deficiencies of the public sanitation system. Urgent measures are necessary to improve the quality of the water on these beaches, and the health and satisfaction of beachgoers.

ADITIONAL INDEX WORDS: *Urban beaches, sewage outlets, Amazon.*

INTRODUCTION

The explosive growth of coastal populations around the World has generated serious environmental and social problems resulting from processes such as the production of solid waste, discharge of effluents, loss of biodiversity, habitats, and water quality, and erosion (Valdemoro and Jiménez, 2006; Steffy and Kilham, 2006; Pereira *et al*., 2007). Many of these problems affect both cultural and recreational activities (DeRuyk *et al*., 1997; Silva, 2002; Silva *et al*., 2008).

These coastal zones are among the most valuable and productive of the World's ecosystems, but are also complex and highly dynamic, exerting considerable pressure on local human and biophysical subsystems. In areas developed for tourism, anthropogenic pressures normally increase considerably, in particular in relation to the demand for infrastructure, water and electricity supplies, and the discharge of effluents, reinforcing the need for the development of coastal management plans (Lau, 2005; Cervantes, *et al.*, 2008).

Brazil encompasses about 47% of the total land area of the South American continent, and has approximately 8,500 km of coastline, of which more than one third is located within the Amazon region. Within this area, landscapes vary considerably, from the densely-populated metropolitan areas of Macapá-Santana (Amapá state), Belém (Pará) and São Luís (Maranhão), through less densely-populated municipalities to isolated areas that are either uninhabited or sparsely occupied by traditional populations (Szlafsztein and Sterr, 2007; Pereira *et al*., 2009).

The population of the city of São Luís has grown considerably in recent years, resulting in increasing environmental problems as a consequence from a lack of adequate infrastructure and services, combined with the unregulated use of land (Silva *et al.*, 2009; Andrade *et al*., 2010). This scenario persists, despite the fact that the city was declared a World Cultural Heritage site by UNESCO in 1997 due to its historical and cultural relevance. The city's beaches are used for fishing, leisure, and tourism, but the presence of sewage outlets that discharge effluents from local bars and other buildings directly onto the beach have affected the water quality of the beaches closest to the center of the city, impeding their use by both local beachgoers and tourists (Silva *et al*., in this issue). In the present study, the effects of this discharge on the quality of the water was evaluated at four of the city's beaches – Ponta de Areia and São Marcos, located in the inner bay, and Calhau and Olho d'Água, in the outer bay.

STUDY AREA

The present study focused on São Luís Island in the Gulf of Maranhão. The littoral 35 km long, between São José and São Marcos bays (Figure 1).

The climate is type AW' (rainy tropical) in the Köppen system, with two principal seasons – rainy and dry. The rainy season normally extends between December (or January) and May (or June), and is characterized by total precipitation in excess of 1,500 mm and temperatures as low as 20°C. By contrast, the dry season is characterized by total precipitation of around 200 mm and temperatures of up to 33°C. Winds also follow a seasonal pattern, with the strongest winds blowing during the dry season, mainly between August and January (primarily northeasterly winds with mean velocities of up to 4.0 m/s), and more moderate winds during the rainy season, mainly between March and July, with mean speeds of less than 3.5 m/s (Porto de Itaqui, 2008).

This coastal zone is dominated by a macrotidal regime, with tide heights ranging up to 7 m during spring tides, strong tidal currents, northeasterly winds, and high precipitation rates and fluvial discharge (DHN, 2010; Silva, *et al.*, 2009).

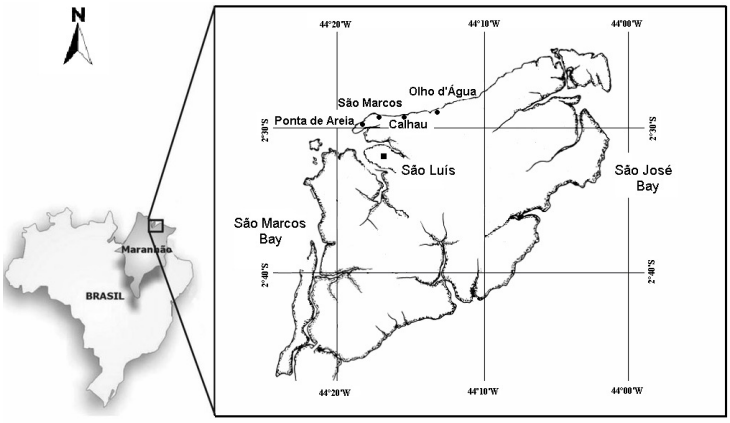

Figure 1. Location of the studied area.

The city of São Luís has a total population of some 958,000 inhabitants (IBGE, 2007). The local economy is based on industry and commerce, although the tourism industry has been growing steadily in recent years. The lack of an adequate public sanitation system is one of the principal problems affecting the quality of the beaches, and the health of beachgoers. Silva *et al.* (2009) counted almost one hundred sewage outlets along the four beaches analyzed in the present study.

METHODS

Meteorological, oceanographic and hydrological data were obtained in four months, representing distinct seasonal conditions: December, 2008 (dry season, minimum river discharge); March, 2009 (rainy season, increasing discharge); June, 2009 (rainy season, maximum discharge); and September, 2009 (dry season, declining discharge). Meteorological data (wind speed and direction, and rainfall) were obtained from the São Luís A203 station of the Brazilian National Institute of Meteorology (December 2008 to November 2009). Hydrodynamic data (tidal range, current speed and significant wave height) were collected over a 12-h period at São Marcos, Calhau and Olho d'água beaches. A mooring was mounted on the seabed (1.8 m depth at low spring tide), with a Sensordata SD 6000 mini-current meter, a CTD (XR-420), and a TWR 2050 wave and tide data logger attached. Tidal currents were measured every 10 min and their direction was recorded relative to the magnetic north. Waves were measured at a rate of 4 Hz (512 samples per 10 min). Tide data were acquired every 2s, with mean values being obtained every 10 min. Hydrological data (dissolved nutrients and thermotolerant coliform concentrations) were obtained from sub-surface water samples collected using a Niskin oceanographic bottle during ebb tide and flood tide periods in the surf zone at the four beaches. In the laboratory, turbidity and pH were measured using a turbidity meter and pHmeter, respectively. Dissolved nutrients were analyzed following Strickland and Parsons (1972) and Grasshoff *et al*. (1983). Chlorophyll *a* and thermotolerant coliform concentrations were measured following the approaches of Strickland and Parsons (1972) and APHA (2007), respectively

RESULTS

The local climate is highly seasonal (Figure 2). During the study period, the rainiest months were March (471.6 mm), April (717.40 mm) and May (538.40 mm). Northeasterly winds predominated during most of the study period and the highest mean wind speeds were recorded in the driest months (December, 7.9 m/s; September, 7.5 m/s; October, 7.2 m/s; November, 8.5 m/s).

During the study period, the greatest tidal range (5.0 m), strongest tidal currents (0.5 m/s) and most accentuated significant wave heights (up to 1.4 m) were recorded in March (Figure 3). The strongest current speeds and highest Hs were recorded at Calhau.

The highest concentrations of nitrites, nitrates, and phosphates were recorded in June, primarily at Ponta de Areia and São Marcos (Figure 4), which are influenced by the discharge of the São Marcos estuary. High concentrations of dissolved nutrients were also observed in December when fluvial discharge was minimal and beachgoers were present in the highest numbers.

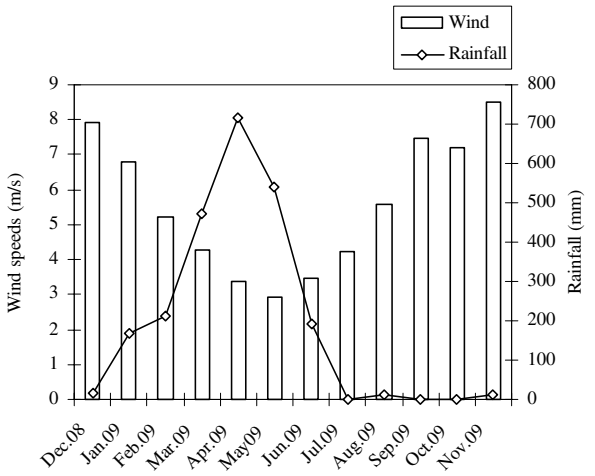

Figure 2. Wind speeds and rainfall pattern.

The highest thermotolerant coliform concentrations (> 1,100 MNP/100ml) were recorded in December and March at Ponta de Areia and São Marcos (Figure 5). Values this high were only recorded at Calhau and Olho d'Água beaches in March, while low values (less than 35 MNP/100ml) were recorded at all four beaches in June and September. Figure 6 shows some of the effects of the sewage discharges in São Luís beaches.

DISCUSSION

The results of the present study indicate that the high concentrations of dissolved nutrients observed in June were related to the high river discharge recorded during this month. In the Amazon region, fluvial discharges normally reach their maximum levels in May and June, and during this period, high concentrations of dissolved nutrients are generally observed along the coast and continental shelf (DeMaster and Pope, 1996; Geyer *et al.*, 1996; Santos *et al*., 2008). The relatively high dissolved nutrient concentrations observed in December, a month of reduced discharge, may be related to the increase in the numbers of beachgoers observed during this part of the year, combined with the deficiencies of the public sanitation system (Silva *et al*., 2009). December is a vacation period, and the high levels of thermotolerant coliforms recorded during this month support the

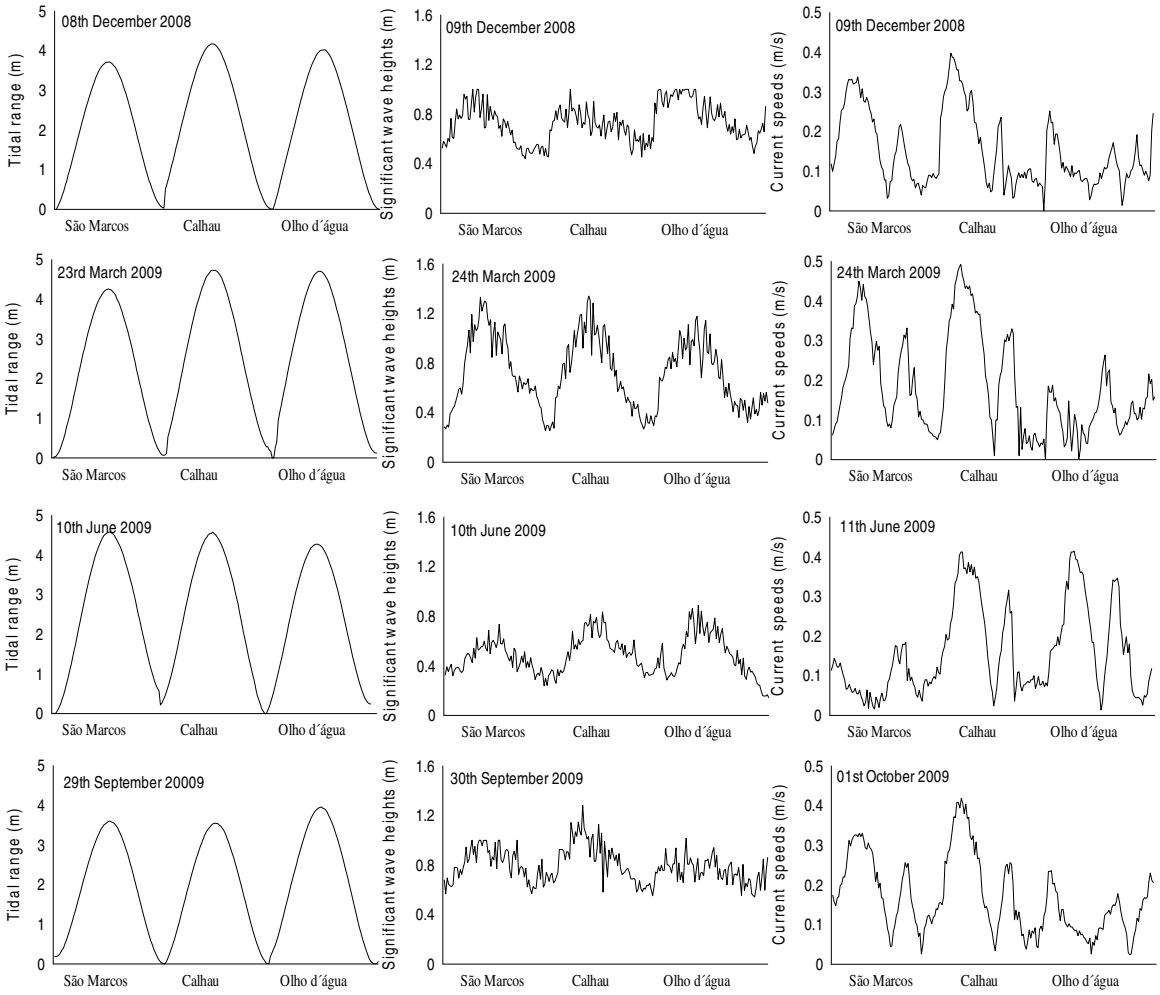

Figure 3. Hydrodynamical variables in São Luís beaches during the studied period.

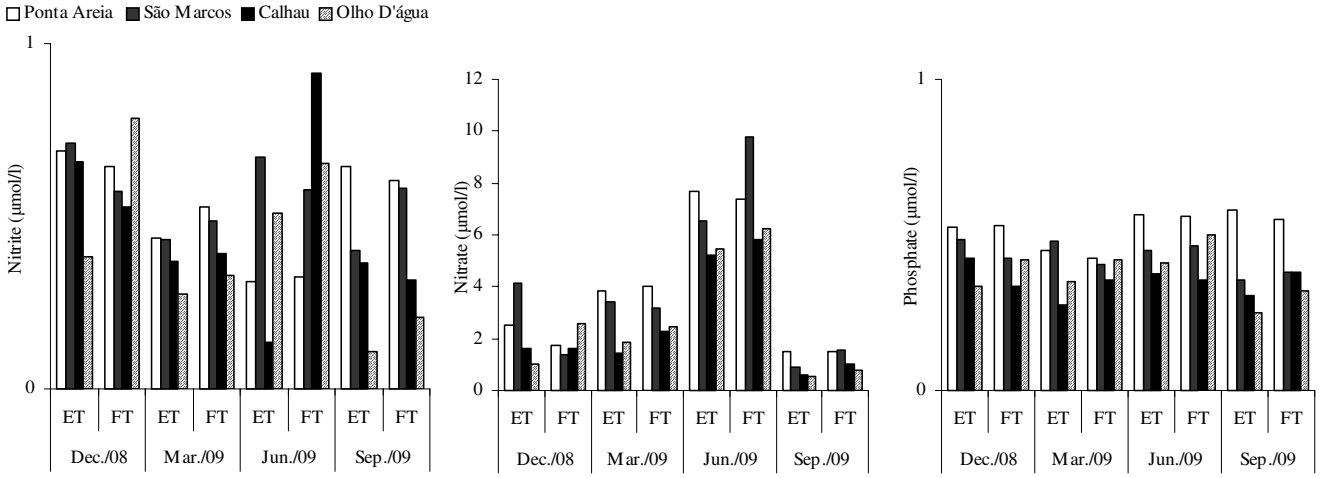

Figure 4. Dissolved nutrient concentrations in São Luís beaches during the studied period.

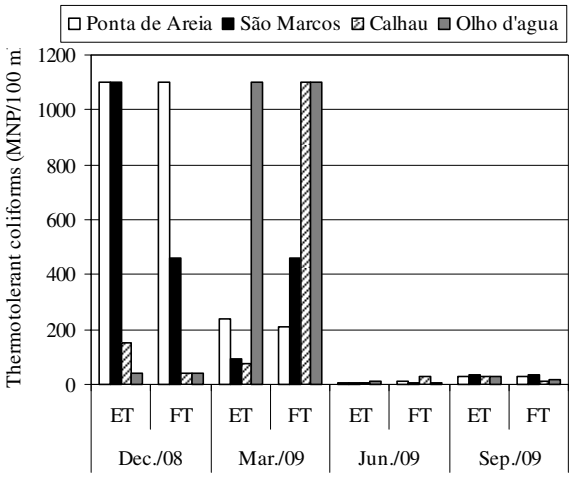

Figure 5. Thermotolerant coliforms data in São Luís beaches.

conclusion that the discharge of sewage from local bars and other establishments onto the beach increased considerably during this period.

The high levels of bacteriological contamination recorded in March were probably related directly to the high precipitations levels during this month, which likely exacerbated the limitations of the public sanitation system. An additional factor may be the relatively high tides recorded in March (DHN, 2009), which may have reached the level of some sewage outlets.

The decrease in bacteriological contamination recorded in June and September was at least partly a consequence of the closure of some sewage outlets and of the prohibition of public bathing on all four beaches in June. This resulted in a sharp decline in the number of beachgoers visiting the area and consequently of the discharge of sewage onto the beaches from the local bars.

The high local hydrodynamic energy contributes to the bacteriological contamination, in particular when the highest tides reach the level of the sewage outlets located in the upper beach zone. However, the rapid turnover of the water provoked by these high tides and strong currents also reduced contamination levels, and both satisfactory and unsatisfactory bacteriological concentrations (according to the criteria of CONAMA, 2005) were recorded during the study period. Similar results were obtained by Pereira *et al*. (2010) for an Amazonian estuary with a similar input of sewage.

CONCLUSIONS

The presence of sewage outlets on the beaches was causing the bacteriological contamination of the water. While the prohibition of public bathing has resulted on a decline in the numbers of beachgoers and, as a consequence, the volume of sewage being discharged, it has also had a negative effect on the local economy. The closure of some of the sewage outlets has helped mitigate the problem, but a number of additional measures would help to ensure the quality of the water on these beaches, and the health and satisfaction of beachgoers, including: (i) the removal of all sewage outlets from the beaches; (ii) the urgent implantation of a public sanitation system throughout the urban area; (iii) the regular monitoring of water quality and other parameters (physical, ecological and social) for the management of bathing areas, and (iv) the regulation of land use in order to minimize pressure on the local coastal environment.

LITERATURE CITED

APHA - American Public Health Association., 2007. Standard Methods for Examination of Water and Wastewater. In: http://www.standard.methods.org/ Articles.cfm.

Figure 6. Sewage discharges and their effects. Sign prohibiting the bathing (A), sewage discharges (B, C) and low number of beachgoers in the bars (C).

Andrade, M.M.N.; Szlafsztein, C.F.; Souza Filho, P.W. de.; Reis, A. A. dos, and Tavares, M.K.G., 2010. A socioeconomic and natural vulnerability index for oil spills in an Amazonian harbor: A case study using GIS and remote sensing. *Journal of Environmental Management*, 9(10), 1972-1980.

Cervantes, O.; Espejel, I.; Arellano, E., and Delhumeau, S. 2008. Users' Perception as a Tool to Improve Urban Beach Planning and Management. *Environmental Management*, 42 (2), 249-264.

CONAMA - Conselho Nacional de Meio Ambiente, 2005. Resolução nº357 de 17 de Março de 2005. In: http://mma.gov.br/conama>.

DeMaster, D.J., Pope, R.H., 1996. Nutrient dynamics in Amazon shelf waters: results from Amassed. *Continental Shelf Research,* 16(3), 263-289.

DHN – Diretoria de Hidrografia e Navegação, 2009. Tábua das marés para 2009. São Luís (Estado do Maranhão). In: http://www.mar.mil.br/~dhn/tabuas.

Geyer, W.R., Beardsley., R.C, Lentz., S.J, Candela., J, Limeburner., R, Johns., W.E, Castro, B.M, Soares, I.D., 1996. Physical oceanography of the Amazon shelf. *Continental Shelf Research*, 16(5-6), 575-616.

Grasshoff, K.; Emrhardt, M., and Kremling, K., 1983. *Methods of Seawater Analysis*. New York: Verlag Chemie, 419p.

IBGE - Instituto Brasileiro de Geografia e Estatística. 2007. In: http://www.ibge.gov.br.

Lau M., 2005. Integrated coastal zone management in the People's Republic of China. An assessment of structural impacts on decision-making processes. *Ocean and Coastal Management*. 48, 115–159.

Pereira, L.C.C.; Medeiros, C.; Jiménez, J.A., and Costa, R.M. da., 2007a. Use and Occupation in the Olinda littoral (NE, Brazil): Guidelines for an Integrated Coastal Management. *Environmental Management*, 40, 210-218.

Pereira, L.C.C.; Monteiro, M.C.; Guimarães, D.O.; Matos, J. B., and Costa, R.M. da, 2010. Seasonal effects of wastewater to the water quality of the Caeté river estuary, Brazilian Amazon. *Annals of the Brazilian Academy of Sciences*, 82(2), 1-12

Porto de Itaqui, 2008. Empresa Maranhense de Administração Portuária – EMAP. In: http:// www.portodoitaqui.ma.gov.br.

Santos, M.L.S., Medeiros, C., Muniz, M., Feitosa, M.L.S., Schwamborn, R., Macedo, S.J., 2008. Influence of the Amazon and Pará' Rivers on water composition and phytoplankton biomass on the adjacent shelf. J. Coastal Res. 24(3), 585-593.

Silva, C. P. da, 2002. Beach Carrying Capacity Assessment: How Important is it?. *Journal of Coastal Research*, SI 36, 190-197.

Silva, I. R. da; Pereira, L.C.C., Guimarães, D. de O.; Trindade , W.N., Asp, N.E., and Costa, R.M. da, 2009. Environmental status of urban beaches in São Luís (Amazon Coast, Brazil). *Journal of Coastal Research*, 56, 1301-1305.

Silva, J.S.; Leal, M.M.V.; Araújo, M.C.B.; Barbosa, S.C.T., and Costa, M.F., 2008. Spatial and Temporal Patterns of Use of Boa Viagem Beach, Northeast Brazil. *Journal of Coastal Research*, 24(1A), 79–86.

Steffy L.Y. and Kilham S.S., 2006. Effects of urbanization and land use on fish communities in Valley Creek watershed, Chester County, Pennsylvania. *Urban Ecosystem*. 9, 119–133.

Strickland, J.D. and Parsons, T.R.A., 1972. Manual of sea water analysis. *Bulletin Fisheries Research Board of Canada*, 125, 1-205.

Strickland, J.D.H. and Parsons, T.R.A., 1968. A practical handbook of sea water analysis. *Bulletin Fisheries Research Board of Canada*, 167, 1-311.

Szlafsztein, C. and Sterr, H., 2007. A GIS-based vulnerability assessment of coastal natural hazard, state of Pará, Brazil. *Journal of Coastal Conservation*, 11, 53-66.

Valdemoro, H.I. and Jiménez, J.A., 2006. The Influence of Shoreline Dynamics on the Use and Exploitation of Mediterranean Tourist Beaches. *Coastal Management*, 34, 405-423.

ACKNOWLEDGEMENTS

The authors would like to thank CNPq, FAPESPA and CAPES for their individual grants. We are also indebted to Stephen Ferrari for his careful correction of the English.